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Research Paper

Eco-Friendly Impact of *Vernonia amygdalina* as Corrosion Inhibitor on Aluminium in Acidic Media

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Abstract

Corrosion inhibition effect of *Vernonia amygdalina* extract on aluminium in 0.5 M HCl solution was studied using gravimetric method at 40 °C temperature. Aluminium coupons of dimension 3x1.5 cm were immersed in test solutions of uninhibited acid and those containing extract concentrations of 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 g/L concentration at intervals of 30 minutes progressively for 150 minutes. The results revealed that *V. amygdalina* could be used as an eco-friendly corrosion inhibitor for aluminium in HCl solution. The corrosion inhibition efficiency of the extract increases with concentrations in the corrosion media. The surface coverage of the extract obeyed Langmuir adsorption isotherm. Hence, the corrosion inhibition effect of the extract was rationalized via adsorption mechanism.

Keywords: *Hydrochloric Acid, Aluminium, Adsorption, Vernonia amygdalina, Inhibition Efficiency*

1. Introduction

Corrosion is one of the major problems in several technical installations involving metals and alloys today hence, prevention mechanism for corrosion of metals is of paramount important to increase their lifespan especially those in aggressive environments. Corrosion protection by using inhibitors has been employed to many systems namely, cooling systems, refinery units, oil and gas production units, boiler etc. (Dong et al, 1999; Abiola & Otaigbe et al, 2008 and Andreeva et al, 2008). The use of inhibitors has now become one of the most practical methods of protecting metals against corrosion and it is becoming popular. Majority of these protecting materials are synthetic chemicals (El-Etre, 2003; Brooman & Toepke, 2006 and Oguzie & Ebenso, 2006) which invariably becomes expensive and hazardous to the environment (Ai et al, 2006), hence the search for natural means of prevention becomes inevitable. It has been reported by Bayol et al, 2008; Mounim et al, 2008; Özcan et al, 2008 and Solomon et al, 2010, that plants of natural origin has organic compound such as amino acids, tannins and alkaloid which have inhibitive effect. The principle of inhibition is the adsorption of the phytochemical molecules in the plant on the surface of the metal resulting in the replacement of water molecule at the corroding surface (Blustein & Zinola, 2004 and Qianku et al, 2008).

Due to economic importance of aluminium and its alloys, its protection against corrosion has attracted much attention (Yingchao et al, 2011 and Zhenhua et al, 2011). The corrosion resistance of aluminium arises from its ability to form a natural oxide film on its surface in a wide variety of media. This oxide film readily undergoes corrosion behaviour in different environments. Corrosion work by Obot et al (2009) reported successful uses of extrudate gum extract from natural plants as corrosion inhibitors of aluminium in alkaline media, hence it become obvious that more are yet to be done since there are lots of natural plants that possess organic compounds having inhibitive effect.

There is evidence of inhibitive properties of *V. amygdalina* extract in reversing the carbon tetrachloride-induced hepatotoxicity in rats (Njoku et al, 2007). The growing interest on utilization of environmentally friendly corrosion inhibitors enhances the present report on the corrosion inhibitive properties of *V. amygdalina* on the corrosion behaviour of aluminium in 0.5M HCl solution.

2. Experimental

2.1. Material Preparation

Aluminium alloy of type AA1100, 1xx was obtained from Systems Metals Industries, Cross River State, Nigeria. Each sheet of 1.8 mm in thickness was pressed cut into 3x1.5 cm coupons. The composition of the aluminium samples was analyzed using Optical Emission Spectrometer and the results as obtained were (wt %) Aluminium (94.10%) and other impurities were: Silicon (0.65%), Iron (1.18%), Magnesium (0.0051%), Zinc (3.60%), Nickel (0.015%), Titanium (0.111%), Strontium (0.317%), Copper (0.042%), Lead (0.012%), , Phosphorus (<0.01%), Beryllium (<0.0001%), Bismuth (<0.001%), Titanium (<0.002%) and Vanadium (0.0035%). The coupons were prepared by degreasing in absolute ethanol, dried in acetone and stored in a desiccator before use.

2.2. Preparation of Inhibitor Extract

Fresh leaves of *V. amygdalina* were obtained from CRIN, Oyo State, Nigeria. The leaves were air dried and milled. Acidic extract of the leaves were prepared by weighing 0.5 g of the milled *V. Amygdalina* in 250 ml round bottom flask and was refluxed with 100 ml of 0.5M HCl solution for 2 hours. The resulting solution was left overnight before filtering and standard solutions of 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 g/L concentrations were prepared and used for the study. The concentration of HCl used for the extraction was analytical grade concentrated HCl (BDH).

2.3. Weight Loss Determination

The weight loss measurements were carried out as described by Eddy et al (2010), using a clean weighed aluminium coupon of 3x1.5 cm and maintained at 40 ^{o}C thermostated water bath. The coupons were retrieved from their corrodent at intervals of 30 minutes progressively for 150 minutes, scrubbed with bristle brush in distilled water and then immersed in ethanol (specific gravity: 0.79) for 2 minutes to remove the corrosion product, dried in acetone and weighed. The percentage Inhibition Efficiency (% I.E.) and the parameter "*theta*" (θ) that represents the weight of the metal surface covered by inhibitor molecules were calculated using the following Equations:

$$\% \, I.E. = 1 - \frac{W_2}{W_1} \; x \; \frac{100}{1} \quad \ldots\ldots 1$$

$$\theta = 1 - \frac{W_2}{W_1} \quad \ldots\ldots 2$$

Where:

W_1 and W_2 are weight losses of aluminium in uninhibited and inhibited solutions respectively

3. Results and Discussion

The variation of weight loss with time for aluminium coupon in 0.5 M HCl solution by *V. amygdalina* is shown in Figure 1. This result denotes that aluminium corrodes in 0.5 M HCl solution but the presence of inhibitor decreased the extent of the metal degradation. However, the weight loss observed in the presence of inhibitor compared with that obtained with the corrodent without the inhibitor was small. This clearly suggests that the extract of *V. amygdalina* inhibits the corrosion of aluminium, hence can serve as corrosion inhibitor for aluminium. The weight loss was generally observed to decrease with increasing concentration of the extract, which correlated with expected increase in the kinetic of adsorption of the constituents of the extract on the aluminium surface. The reasons for this particular behaviour are that the surface may no longer adsorb after a particular concentration, and that the inhibitor may have maximum performance concentration.

The variation of the weight loss with percentage Inhibition Efficiency (% I.E.) at varying concentrations of the *V. amygdalina* extract is shown in Figure 2. The inhibition efficiency was observed to increase with increasing concentration of the acid extract of *V. amygdalina*, which can be attributed to adsorption of inhibitor on the aluminium coupon surface. This observation followed the same pattern reported by Abiola & James (2010), for zinc as well as other metals such as aluminium in acidic media. The inhibitive action can be attributed to binding unto the cathodic sites on the metal surface and its corrosion inhibitive action increases with concentration. However, tannin containing plants extracts are reported to exhibit varying inhibition efficiency and inhibition mechanism (Loto & Popoola, 2011). The inhibition tendency of tannin extracts is a function of the molecular properties of its constituents. This in turns determines the molecular reactivity, which as well is related to its adsorbability. This may, in part, accounts for the differences in the inhibition efficiencies and mechanisms reported for different tannins sources. For example, it has been observed that natural tannins extract from pine exhibit better corrosion inhibition and better adherence to metallic substrates than the tannins extracted from Acacia (Matamala et al, 2000).

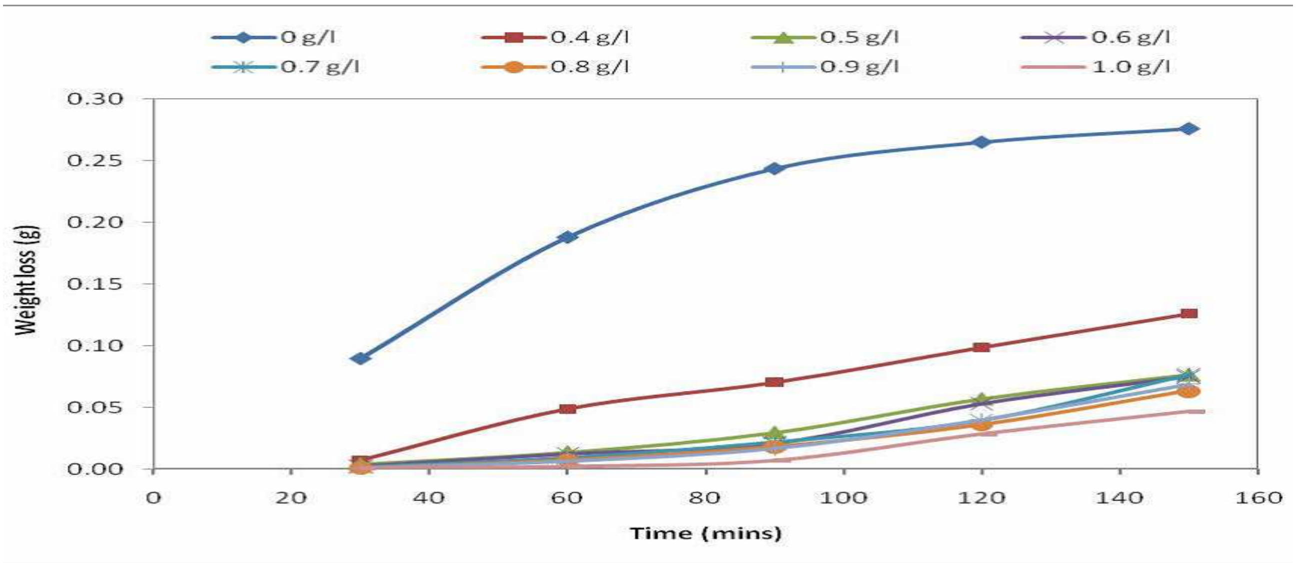

Figure 1. Variation of Weight Loss with Time (minutes) Inhibition of Aluminium Coupons for Different Concentrations of *Vernonia amygdalina* Extract in 0.5 M HCl at 40 °C

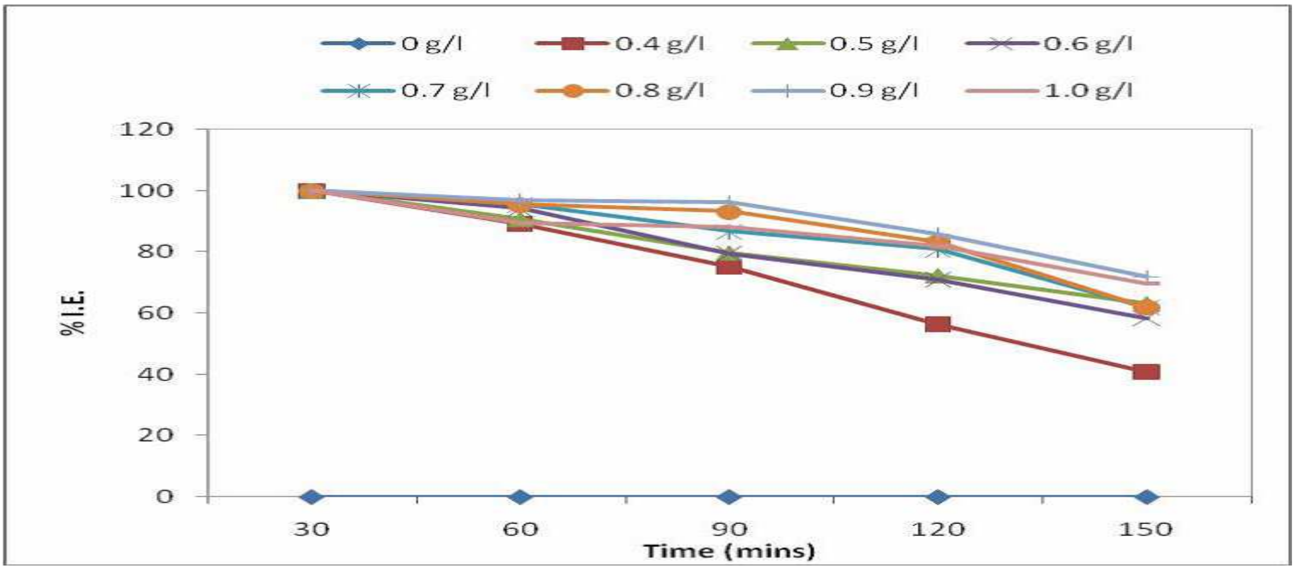

Figure 2. Variation of Inhibition Efficiency (% I.E.) of *Vernonia amygdalina* on Aluminium Coupons at Different Exposure Time in 0.5 M HCl Solution Using Gravimetric Technique at 40 °C

There was a critical concentration detected from the extract of *V. amygdalina* in the inhibition of aluminium. This concentration was observed using 0.8 g/L at 120-150 minutes (Figure 2). This phenomenon was also reported in other studies (Abdel-Gaber et al, 2006), in which the inhibitive action of some plant extracts on the corrosion of metal in acidic media was found to increase with increasing concentration of the plant extract up to a critical concentration and afterwards decreased with increased time.

The effect of immersion time on the inhibition efficiency of *V. amygdalina* leaves is shown in Figure 3. The adsorption of the adsorbate on the surface of the electrode is regarded as substitution adsorption process between adsorbate in the aqueous phase and the adsorbed water molecules (Moretti et al, 1994). Efforts were made to fit θ values to Freundlich, Langmuir, Bockris-Swinkels and Temkin isotherms. The best fit was obtained using the Langmuir isotherm (Equations 3 and 4).

$$\frac{\theta}{\theta - 1} = KC \quad \ldots\ldots\ldots\ldots 3$$

$$\frac{C}{\theta} = \frac{1}{K} + C \quad \ldots\ldots\ldots\ldots 4$$

The plot of C/θ against C gives a straight line (with R^2 value of 0.988) as it was observed in Figure 3. This implies that the adsorption of *V. amygdalina* on the aluminium sheet, in 0.5M HCl solution, obeys Langmuir's adsorption isotherm principle which means there is no interaction between the adsorbent molecules at the surface of aluminium metal. This also infers that the adsorbates were chemisorbed on the aluminium coupons thereby inhibiting the metal. Therefore, chemisorption mechanism in which a monolayer protective coverage of the aluminium surface by the adsorbates accounts for the corrosion inhibition properties of the extract.

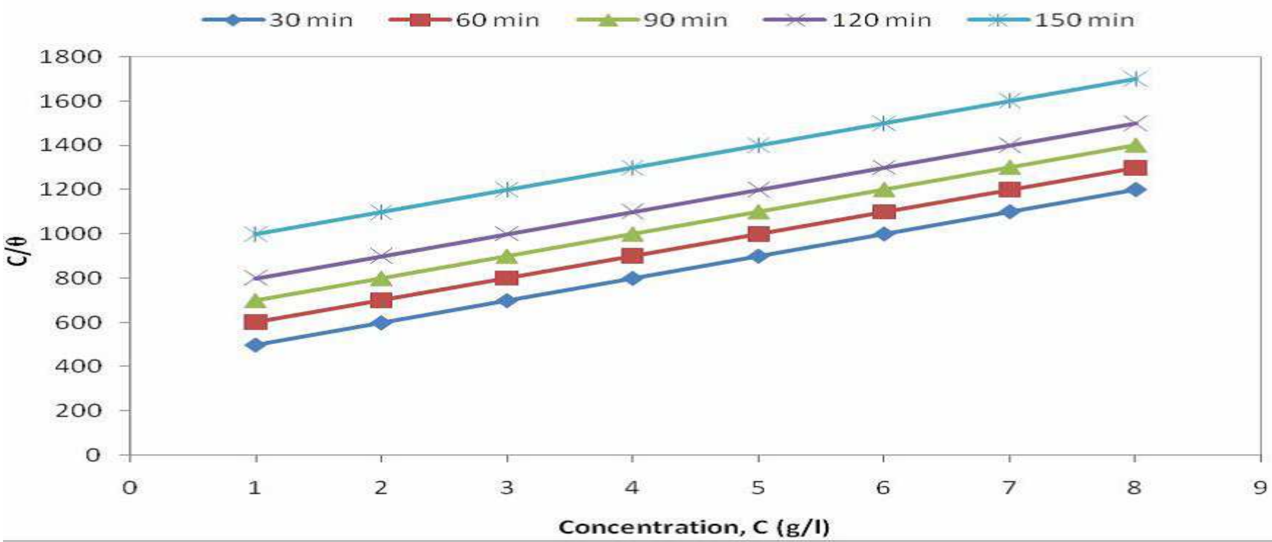

Figure 3. Langmuir Adsorption Isotherm Relationship Between C/θ and C for Using *Vernonia amygdalina* as Inhibitor for Aluminium at Different Exposure Time in 0.5M HCl

4. Conclusion

Consideration of the results of the general corrosion revealed the following conclusions:

- The corrosion rate in HCl solution containing the extract (inhibitor) decreases with increase in the concentration of the inhibitor.
- The percentage inhibition efficiency (% I.E.) increased with concentration of the extract.
- The extract offers an excellent anti-corrosive effect for aluminium in 0.5M HCl environment.
- The adsorption of the extract on the aluminium surface follows Langmuir adsorption isotherm.

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